STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

GEOLOGY AND MINERAL DEPOSITS OF THE CALAVERITAS QUADRANGLE CALAVERAS COUNTY, CALIFORNIA

SPECIAL REPORT 40

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GEOLOGY AND MINERAL DEPOSITS OF THE CALAVERITAS QUADRANGLE CALAVERAS COUNTY, CALIFORNIA

By LORIN D. CLARK
Geological Survey, U. S. Department of the Interior

Price $1.75

GEOLOGY OF THE CALAVERITAS QUADRANGLE, CALAVERAS COUNTY, CALIFORNIA*

By Lorin D. Clark **

OUTLINE OF REPORT

Illustrations

ABSTRACT

The Calaveritas quadrangle is in the western foothills the Sierra Nevada, east of the Mother Lode gold belt. ost of the quadrangle is underlain by a strongly deormed bedrock complex that is locally covered by small posits of undeformed stream gravels and rhyolite tuff.

The bedrock complex consists of metasedimentary cks of Paleozoic age—known as the Calaveras formaon and the green schist sequence—and intrusive and eta-intrusive rocks of Mesozoic age. More than threeurths of the quadrangle is underlain by rocks of the alaveras formation, which consists largely of interedded graphitic schist and quartzite but includes scatred lenses of limestone. A sequence of green schists, signated "amphibolite schist" on earlier maps, is resent in the southwest corner of the quadrangle and robably underlies the Calaveras formation. Intrusive nd meta-intrusive rocks include irregular masses of ranodiorite and ultramafic rocks, and small diorite ikes; they cannot be dated more closely than postariposa and pre-Chico. Metasedimentary rocks of the edrock complex have undergone two periods of deforation: the first and most intense formed the folds and chistosity, and the second formed slip cleavage in both ne metasedimentary and the intrusive rocks. The slip eavage is parallel to the Mother Lode vein system and uts across structures formed during the earlier period f deformation.

Elevated stream gravels rest unconformably on the bedrock complex and are overlain by interbedded gravel and rhyolite tuff that are in turn overlain by welded rhyolite tuffs. The gravels and tuffs range in age from Eocene to Miocene and possibly lower Pliocene.

Gold, historically the most important mineral commodity produced in this quadrangle, has now been surpassed in importance by limestone, used in the manufacture of cement. No other minerals are being produced in significant amounts, although deposits of pozzolanic material, amphibole asbestos, talc, chromite, copper, and iron, of potential value are known.

INTRODUCTION

The Calaveritas quadrangle is in the western foothills of the Sierra Nevada in Calaveras County, California (see fig. 1). It lies east of the Mother Lode gold belt; its western boundary is 3 miles east of San Andreas, one of the principal towns of the region. Local relief is moderate except in the vicinity of the main streams, which have cut steep-walled canyons. The lowest point, at an altitude of 950 feet, is on San Antonio Creek near the southwest corner of the quadrangle; the highest point, at an altitude of 2,794 feet, is on a hill near the northwest corner of the quadrangle; thus the total relief is 1,844 feet. The greatest local relief, 1,000 feet, is near Fricot Ranch school in the east-central part of the quadrangle. The climate is intermediate between the Mediterranean type of the Central Valley and the more severe Alpine type of the higher mountains. The mean annual precipitation, measured at San Andreas, is 28 inches. Most of the precipitation, largely in the form of rain, falls during the winter; the smaller streams dry up during the summer.

The quadrangle was mapped by the U. S. Geological Survey as part of a larger program in the Mother Lode region under a cooperative arrangement between that agency and the California State Division of Mines. Field work, done during 6 months in 1950 and 2 months in 1951; consisted in surface mapping at a scale of 1:20,000, and in studying in detail quarry No. 4 of the Calaveras Cement Co. L. Allan Brubaker ably assisted in the field work for 2 months in 1950 and aided in the tabulation of mines. This is a preliminary report on a continuing mapping program in the San Andreas 15-minute quadrangle. The cooperation of officials of the Calaveras Cement Co. in carrying out the investigation is gratefully acknowledged.

The Calaveritas quadrangle has not previously been studied in detail. It has been included, however, in the more general studies made by Turner (1894) and by Ransome (1900). Maps by Crawford and Storms (Storms, 1894, p. 482) and by Lindgren (1911) show river channels and gravel deposits of Tertiary age in the quadrangle. Several publications by the California State Division of Mines, listed with the tabulations of gold mines in this report, provide useful information on individual mines in the quadrangle. Jenkins (1948) gives

* Prepared by U. S. Geological Survey in cooperation with California State Division of Mines; publication authorized by the Director, U. S. Geological Survey.

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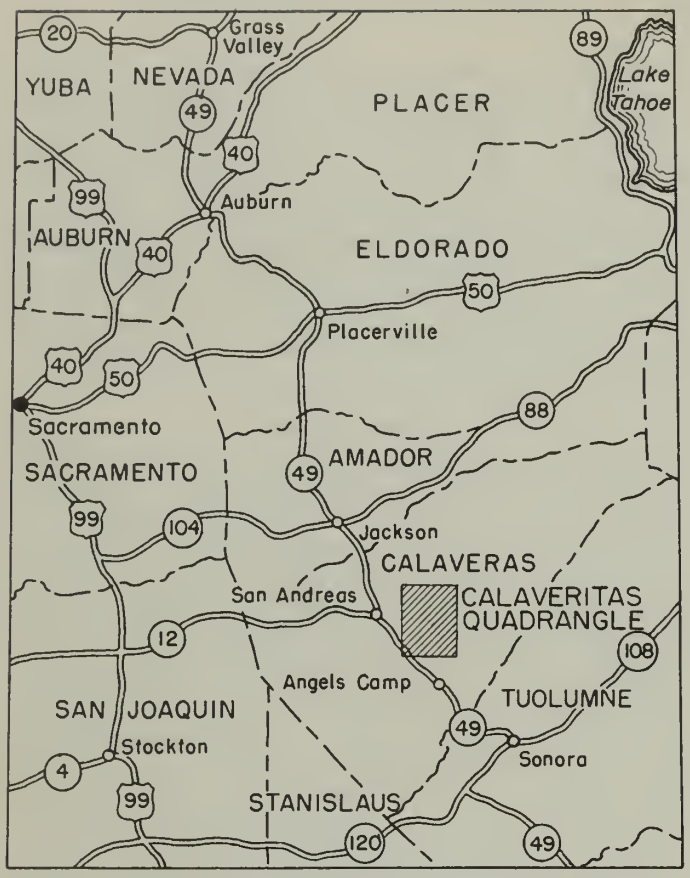


FIGURE 1. Index map showing location of Calaveritas quadrangle, California

an interesting account of the general geology and history of the Mother Lode region.

GENERAL GEOLOGY

Rocks of the Calaveritas quadrangle can be divided into a deformed bedrock complex and undisturbed surficial deposits. Table 1 shows the sequence and character of rocks in the quadrangle. The bedrock complex consists of a green schist sequence, the Calaveras formation, and intrusive granodiorite, ultramafic masses, and minor rock types. Above the complex are auriferous gravels and the rhyolite tuff and interbedded gravels of the Valley Springs formation; these underlie only a very small part of the quadrangle.

The green schist sequence in this quadrangle comprises three kinds of rock: (1) porphyroblastic actinolite schist, (2) fine-grained, thin-bedded siliceous rocks, and (3) phyllite. Porphyroblastic actinolite schist is most abundant, but the thin-bedded siliceous rocks are common. The phyllite is prominent in adjoining quadrangles to the south and west but underlies only the extreme southwest corner of this quadrangle. All three rocks consist of the same assemblage of minerals, but in different proportions. The most abundant minerals are quartz, actinolite, clinozoisite, epidote, and talc (?). Graded bedding in the green schist suggests that it underlies the Calaveras formation, but a more precise age has not been determined. The contact between the green schist and the Calaveras formation is transitional in most places.

The Calaveras formation, probably of Mississippian age, consists chiefly of interbedded black graphitic schist and quartzite with scattered lenses of limestone. Conglomerates were found in schist of the Calaveras formation at two localities near the contact with the green schist sequence. Tectonic breccias consisting of ellipsoidal to lenticular fragments of quartzite in a matrix of graphitic schist are widely distributed.

The limestones range from coarse-grained low-magnesia limestone to fine-grained dolomitic limestone or dolomite. Bedding is not preserved except in rare thin-bedded argillaceous limestones, but black streaks containing graphite are probably parallel to the bedding in most places. Extensive underground solution of the limestones has led to the development of caves, which locally are filled with debris formed by slumping.

Remnants of stream deposits formed in the early Tertiary valleys are widely distributed in the quadrangle and form small isolated patches, most of which are well above the level of the present drainage. The oldest of these deposits consists of auriferous gravel of Eocene age that rests on bedrock and is overlain by gravel containing lenticular beds of rhyolite tuff. This, in turn, is overlain in the northeastern part of the quadrangle by two layers of welded rhyolite tuff separated by nonwelded rhyolite tuff. Beds containing rhyolite tuff are correlated with the Valley Springs formation, which is tentatively considered to be of Miocene age. The Oligocene may be represented by an unconformity that could easily escape recognition, or may be represented by the lower beds of the Valley

Table 1. Sequence and character of rocks in Calaveritas quadrangle.

Age	Rock units	Character
Recent	Alluvium	Gravel in present stream beds, and debris from hydraulic mines.
	- - - - Unconformity - - - -	
Miocene(?)—Pliocene(?)	Auriferous gravel	Auriferous coarse gravel containing andesite detritus.
	- - - - Unconformity ? - - -	
Miocene(?)	Valley Springs formation	Interbedded gravel and rhyolite tuff, welded rhyolite tuff, and nonwelded rhyolite tuff with minor amounts of interbedded gravel.
	- - - - Unconformity ? - - -	
Eocene	Auriferous gravel	Auriferous coarse gravel and interbedded sand. Pebbles derived from bedrock complex.
	- - Angular unconformity - -	
?	Diorite dikes	Fine-grained, dark gray, in some places containing hornblende and feldspar phenocrysts.
Jurassic(?)	Granodiorite intrusives, hornblende gabbro, and associated mixed rocks	Equigranular coarse-grained granodiorite; porphyritic hornblende gabbro; and rocks of intermediate composition.
Jurassic(?)	Ultramafic masses	Largely schistose talc, locally massive dark green antigorite rock. Probably derived from serpentine.
	- - - - Unconformity - - - -	
Mississippian(?)	Calaveras formation	Interbedded graphitic schist and quartzite, with scattered limestone lenses. Tectonic breccia is common, conglomerate rare.
?	Green schist sequence	Porphyroblastic actinolite schist, fine-grained siliceous rock, and phyllite.

Springs formation. Some of the auriferous gravel in the southwestern part of the quadrangle is younger than Eocene and may be in part as young as lower Pliocene.

Intrusive and meta-intrusive rocks include granodiorite, ultramafic rocks, and diorite. A large mass of granodiorite extends into the quadrangle from the west, and small masses are widely distributed in the quadrangle. Associated with the large mass of granodiorite are hornblende gabbro and mixed rocks intermediate in composition between the hornblende gabbro and the granodiorite. These mixed rocks are in the border zone of the granodiorite and form several small masses near Mountain Ranch. Ultramafic rocks are present chiefly as thin tabular masses that are concordant with the structure of the enclosing rocks. Diorite forms thin dikes that occupy joints in the schist. In the absence of evidence leading to an accurate age assignment, the granodiorite and ultramafic masses have been designated Jurassic (?). The diorite is younger than the granodiorite and ultramafic rocks, though of undetermined age.

The most prominent structural feature of the quadrangle is the complex fold, probably an anticline, in the southern part of the quadrangle. The fold trends eastward, in contrast to the general northwest structural trend of the region. High-angle faults may well be important structural features, but it has been possible to map only short segments of faults that truncate limestone lenses.

The major structural features of the quadrangle are difficult to define because key horizons are few and bedding has been destroyed by shearing throughout much of the area. Schistosity is the dominant planar element. Slip cleavage, consisting of microfaults and fractures that offset the schistosity, is best developed in the southwestern part of the quadrangle, becoming more obscure toward the northeast. It dips steeply northeast and trends northwest, parallel to the trend of the Mother Lode belt. Linear elements include elongate quartzite fragments in tectonic breccias, stretched conglomerate pebbles, and the axes of minor folds.

Rock Units

The Green Schist Sequence

Rocks of the green schist sequence are present in the southern part of the Calaveritas quadrangle, where they occur chiefly in the core of a major fold. Three lithologic types comprise most of the green schist sequence in this quadrangle. In order of decreasing abundance they are: (1) thick, porphyroblastic actinolite schist, (2) fine-grained, silica-rich rocks, and (3) phyllite. Each lithologic type may constitute a single stratigraphic unit, but its relationship to the other types is not established. With the exception of the silica-rich type, rocks in the green schist sequence are less resistant to erosion than those of the Calaveras formation; much of the valley-bottom pasture land in the south part of the quadrangle is underlain by green schist.

In this quadrangle the thick-bedded porphyroblastic schist is composed of closely spaced, dark-green actinolite crystals 0.5 to 8 mm long in a fine-grained matrix. The weathered rock is yellow-green to green-brown, but fresh specimens are bright green. In general, schistosity is not well developed, and in some places the rock is almost massive. Thin interbeds of argillaceous or silty material are common. Near the contact of the green schist sequence with the Calaveras formation in secs. 32 and 33, T. 4 N., R. 13 E. (see geologic map, pl. 1), some of the argillaceous layers contain sandy beds in which graded bedding can be readily distinguished.

The fine-grained silica-rich rocks of the green schist sequence underlie the ridge southwest of Simmons Point, in the southwest corner of the quadrangle. They are best exposed 300 feet beyond the west boundary of the quadrangle in San Antonio Creek. Typically, the rock is thin-bedded and consists of dark-gray argillaceous bands alternating with bands of microcrystalline quartz. Graded bedding is rare.

The phyllite, a fine-grained, light yellow-green to gray rock, underlies a gently sloping area in the extreme southwest corner of the quadrangle. In the adjoining quadrangles (Eric et al., 1954; Stromquist) it has been traced for several miles northwest and southeast from this area.

Within the area of green schist are several narrow bands of black phyllite or schist that are difficult to correlate—they look like some of the schists of the Calaveras formation. Some of this material, particularly in the southwestern part of the quadrangle, seems, because of its outcrop pattern, to be infolded schist of the Calaveras formation. Interpretation of the narrow bands near the eastern end of the main area of green schist is more difficult—they may be either interbedded with the green schist or infolded parts of the Calaveras formation.

Both the porphyroblastic and the fine-grained silica-rich phases of the green schist sequence are composed largely of quartz, actinolite, clinozoisite, epidote, and talc (or muscovite). A small amount of chlorite is present in all specimens examined. Minor minerals present in one or more specimens are twinned oligoclase, untwinned feldspar, biotite, sphene, garnet, and pyrite. One specimen of porphyroblastic schist contains about 30 percent of calcite. In thin section the original clastic character of the rocks is not readily apparent, and all mineral grains appear to be products of recrystallization. The most significant features of the chemical composition of the green schist series as indicated by the mineralogy are the large amounts of silica and lime and the small amount of alumina.

Calaveras Formation

More than three-fourths of the Calaveritas quadrangle is underlain by rocks of the Calaveras formation. These rocks consist largely of graphitic schist and fine-grained quartzite. Interbedded with these are scattered limestone lenses, which have been mapped separately, and a few lenses of chlorite schist and talc schist that are too small to be differentiated on the map. Tectonic breccia is common, and conglomerate is present locally. The schists are, in general, deeply weathered, and they are poorly exposed except in stream bottoms.

The thickness of the Calaveras formation has not been established. If it is assumed that the beds are not repeated, a thickness of more than 35,000 feet in this quadrangle alone is indicated. Such a figure seems excessive, particularly for material that apparently accumulated very slowly—it is more likely that the beds are repeated by folds and faults.

Turner's assignment (1894) of these rocks to the Calaveras formation is followed in this report. Although the Calaveras is a catch-all formation, no attempt to redefine it is made here, because of the small size of the area studied and because only one contact of the sequence of graphitic schist, quartzite, and limestone has been mapped. No diagnostic fossils have been found in the Calaveritas quadrangle.

Schist and Quartzite. The graphitic schist and quartzite are thin-bedded to laminated. They commonly are interbedded in alternating layers, but locally groups of beds totaling 25 feet or more in thickness consist of only one of the rock types. Locally, in quartzite beds about half an inch thick, graded bedding is suggested by a color gradation from light to dark gray across individual beds. The gradations did not appear clear enough to provide reliable determinations of tops of beds. The graphitic schist has either a greasy or a satiny luster, depending on whether graphite or mica is dominant on cleavage surfaces. On fresh surfaces broken normal to the foliation the more massive forms of graphitic schist are vitreous, owing to the high proportion of silica. Weathered graphitic schist is dull black or gray. The quartzite is gray to white, and very fine-grained; individual grains cannot be distinguished with the hand lens. On fresh surfaces the quartzite is vitreous, but its weathered surfaces have a sugary appearance.

This quartzite is microcrystalline and probably is derived from chert or from quartz siltstone rather than sandstone, and is thus not in the category of quartzite as generally defined—i.e., derived from quartz sandstone (Holmes, 1928; Rice, 1951). The term "quartzite" is used here, however, in the absence of another term generally accepted to denote a metamorphic rock derived from quartz of uncertain origin or from clastic quartz finer than sand. Grout (1932) and Durrell (1940) are among those who have previously followed this broad usage.

Ilmenite is common in the graphitic schist, and in a few places tabular crystals of ilmenite as much as 1 cm long comprise about 2 percent of the rock. Titanium determinations made by the U. S. Geological Survey (see table 2), on 5 samples representative of zones containing the most ilmenite, however, show that these zones contain only a little more titanium than average shale and schist (Clark, 1924, p. 631). Sphene is common in the parts of the schist that do not contain ilmenite.

Table 2. TiO_2 in ilmenite-bearing schist.

Sample number	TiO_2 percent
1	0.66
2	1.0
3	0.58
4	0.70
5	0.95
6	0.74

Analyst: Leonard Shapiro

All samples are chip samples representing the stated thickness across the strike.

1. 20 feet. Black siliceous graphitic schist. Murray Creek, NW¼NW¼ sec. 7, T. 4 N., R. 13 E.
2. 100 feet. Black, massive, siliceous graphitic garnet-bearing rock. El Dorado Creek, SW¼SE¼ sec. 5, T. 4 N., R. 13 E.
3. 9 feet. Black siliceous graphitic schist. SE¼NE¼ sec. 3, T. 4 N., R. 13 E.
4. 150 feet. Vitreous black siliceous graphitic schist, McKinney Creek, SW¼SE¼ sec. 11, T. 4 N., R. 13 E.
5. Boulder in stream bed. Black vitreous siliceous graphitic schist. McKinney Creek, NE¼NE¼ sec. 22, T. 4 N., R. 13 E.
6. 5 feet. Vitreous black siliceous graphitic schist. McKinney Creek, NE¼NE¼ sec. 22, T. 4 N., R. 13 E.

Quartz is the dominant mineral in the schist as well as in the quartzite. Other common minerals in the schist and quartzite are muscovite, biotite, and graphite. Feldspar is absent in most specimens, but one specimen of schist contains 20 percent of oligoclase. Specular hematite and either ilmenite or titanite are common accessory minerals; and epidote, clinozoisite, pyrite, and garnet were seen in some specimens of schist and quartzite. Chlorite is secondary after biotite, and also occurs in veinlets. The salient features of the mineralogy are the presence of graphite and the abundance of quartz throughout the section.

That quartz grains show no evidence of strain indicates that these grains are products of recrystallization. The textures are schistose and granoblastic, and the original clastic texture is obscure. However, gradation in grain size across a quartzite bed in one thin section may reflect original graded bedding.

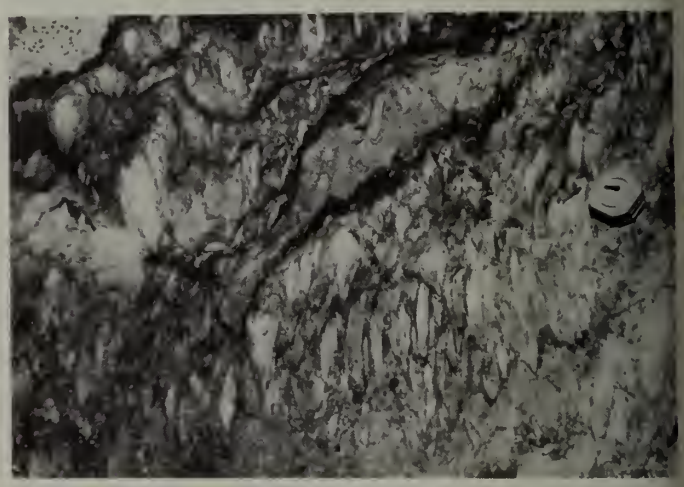


FIGURE 2. Folded tectonic breccia, black graphitic schist, and gray quartzite in the Calaveras formation, McKinney Creek, southwest corner of sec. 14, T. 4 N., R. 13 E. Breccia fragments are parallel to schistosity and to the axial planes of the folds. Gray, granular patches on left are surficial sand.

Tectonic breccia and stretched conglomerate. Two types of fragmental rocks are found in the Calaveras formation. These are: (1) tectonic breccia, widely distributed throughout the formation, and (2) stretched conglomerate, present locally, which superficially resembles the tectonic breccia. The wide distribution of tectonic breccia throughout the schist of the Calaveras formation (fig. 2) may be responsible for an often repeated statement to the effect that conglomerates are common in this formation (e.g., Ransome, 1900). Field observations of the tectonic breccia in this quadrangle strongly suggest that the breccia was developed by the fragmentation of interbedded quartzite and graphitic schist. The sedimentary origin of the material identified as stretched conglomerate is not as well established.

In distinguishing between stretched conglomerate and tectonic breccia in these strongly deformed rocks, the present shape and attitude of the pebbles or fragments are of little value, because these characteristics are determined by the action of later processes of deformation upon pre-existing fragments. In the stretched conglomerates the fragments are primary and result from epi-

lastic processes; in the tectonic breccias the fragments re secondary and result from fragmentation by catalastic processes during the earlier stages of deformaion. Further deformation tends to modify the shape of oth primary and secondary fragments and to bring hem into alinement with some axis or plane of deforıation.

The tectonic breccia consists of fragments of quartzte in a matrix of graphitic schist. Almost invariably the ragments are elongate and show a strong preferred rientation. In the finest breccia noted the fragments are igar-shaped and are of the order of 30 mm in length nd 2 mm in diameter; in the coarsest breccias most fragıents are lenticular and are commonly about 5 inches ong, 3 inches wide, and an inch thick. The fabric and rain size of other breccias are intermediate. In spite of he abundance of tectonic breccia of this character, breccia of similar composition and texture has not been ound in places where the bedding is well preserved. nstead, breccia is confined to areas where the bedding as been destroyed by shearing. This strongly suggests hat the breccia is genetically related to shearing.

Early stages in the development of tectonic breccia an be observed in some moderately sheared rocks of the Calaveras formation. Quartzite layers 1 to 30 mm thick, nterbedded with graphic schist, have been broken by hearing along schistosity surfaces into very elongate arallel blades and prisms; length-width-thickness ratios f the order of 100-3-1 have been measured, and probbly many fragments are proportionately longer. The ectonic breccia has apparently been formed by further ragmentation of these very elongate and mechanically nstable elements.

Elongate fragments have formed not only where the ttitudes of bedding and schistosity differ appreciably. They have formed also in some places where the two tructures are generally parallel or nearly so; in such laces the quartzite beds have been broken into long lades because the schistosity surfaces are corrugated, o that a schistosity surface crosses and recrosses the ame quartzite bed.

Some features of the composition and texture of the tretched conglomerates in differing from those of the ectonic breccias seem to indicate, but do not concluively prove, a different mode of origin. The tectonic reccias consist of fragments of quartzite in a matrix f graphitic schist; the stretched conglomerates show nore variety in pebble composition. The conglomerates xposed in the road cut of Ponderosa Way in the SW¼-SW¼ sec. 35, T. 4 N., R. 13 E., contain pebbles of grahitic schist and fine-grained green sandstone probably lerived from the green schist sequence. The conglomerates exposed in the bed of San Domingo Creek in the ortheast corner of sec. 2, T. 3 N., R. 13 E., contain ebbles of light-gray quartzite, black quartzite or recrystallized chert, and, rarely, marble.

At both of these localities the stretched pebbles (or obbles) are as much as 18 inches long and 2 inches in liameter; the smaller grains reach a lower limit of less han 1 mm. The grain-size distribution of the conglomerates seems to be more nearly uniform than that of the tectonic breccias, in most of which the fragments of intermediate size are relatively much less abundant.

The coarse conglomerate in the bed of San Domingo Creek contains interbedded layers of medium-grained material in which most fragments are 1 to 2 mm. in diameter, and the diameters of the largest grains do not exceed 3 mm. Interlayering of coarse- and medium-grained material is common in undeformed conglomerates elsewhere, but such interlayering has not been found in the tectonic breccias of this quadrangle.

Limestone. Limestone is restricted to the Calaveras formation and is present in pods or lenses rather than in continuous beds. The largest limestone lens lies in the northeast part of the quadrangle; smaller lenses are grouped in an elongate belt in the southern part of the quadrangle parallel to the north contact of the main mass of green schist with the Calaveras formation. Limestone masses are comparatively well exposed, probably owing to the craggy character of their surfaces. Even in areas where schist is buried beneath residual mantle and slope wash, enough low limestone crags project above the surface of the ground to delineate the extent of the mass. The term "limestone" is used locally to include carbonate rocks ranging in composition from calcite to dolomite. In this report the term "limestone," where unmodified, is used in this broad sense.

Coarse-grained low-magnesia limestone and fine-grained dolomite or dolomitic limestone are the most common carbonate rocks. A small part of the limestone is thin-bedded and fine-grained and is probably argillaceous. The limestone ranges from white to dark gray, depending on the amount of admixed graphite. A fetid odor is common in freshly broken specimens. Clastic grains of sand size are absent, but insoluble residues contain silt-size grains of quartz and rare heavy minerals. No oolitic limestone was found. Tremolite of secondary origin is abundant locally.

Most limestones in the area are at least partly dolomitized, and a complete gradation from nearly pure calcite to dolomite could probably be found within some limestone masses. Boundaries between dolomitized rock and low-magnesia limestones are very irregular, and the two rocks interfinger parallel to the foliation of the schist with which they are associated. In the large lens of limestone that underlies Cave City and Mountain Ranch, in the northeast part of the quadrangle, the most prominent exposures are of dolomite, suggesting that this rock is more resistant to weathering than the low-magnesia limestones. Parts of some of the smaller limestone pods have been partly replaced by massive gray and brown ferruginous chert. This chert contains opal and is finer-grained than the quartzite associated with the schist.

The discontinuity of the limestone masses may reflect original lenticularity or it may be the result of tectonic movements that have disrupted extensive blanket deposits; no evidence was found that permits evaluation of these two possible modes of origin. Faulting and the solution of the limestone by ground water have no doubt caused part of the present discontinuity. Truncation of three marble beds by faults that trend at large angles to the strike of the marble is obvious in the north part of sec. 22, T. 4 N., R. 13 E. South of the center of the same section another marble mass has been cut out by a fault, or shear zone, that is generally parallel to the strike of the beds.

Caves and detritus-filled cavities are a common feature in the limestones of this area. The large limestone mass in the northeast part of the quadrangle contains several caves with openings to the surface. The largest cave, operated commercially as a tourist attraction for several years, is in the northeast side of the limestone mass near Cave City. Two open caves have been found at the Calaveras Cement Company quarry No. 4; one beneath the intermediate level was opened by quarry operations, and the other was encountered by a diamond-drill boring in Old Gulch, south of the quarry. Slumped material filling former caves is exposed in some of the quarry walls.

The development of the caves in the large limestone mass in the northeast part of the quadrangle was controlled, in part at least, by joints and by bedding or schistosity planes. Most rooms are elongate parallel to the strike of the steeply dipping bedding and schistosity, but some are parallel to the joints. Some filled caves in the south part of quarry No. 4 are in the structural trough that is formed by the intersection of the footwall contact with the fault contact. However, in the northeast extension of the quarry, where filled caves are more common, the factors controlling their formation are not apparent. The possibility that the low-magnesia limestone has yielded more readily to solution than the high-magnesia limestone seems reasonable, but this hypothesis has not been investigated.

The materials that partly or completely fill the caves are of diverse origin. Sticky dark-gray clay, probably a residue from the dissolved limestone, composes the floors of the open caves and is mixed with material of other origin in some of the filled caves. In quarry No. 4 slumped material is a common cave filling. In some places such material consists of limestone blocks surrounded by red or gray clay. In other places it is a chaotic mixture of limestone and schist blocks and gray clay. Rarely, the fill material consists not of jumbled blocks but of schist that is draped into solution cavities without loss of the continuity of layering of the schist. In such places the slumping of the schist was probably slow, and was contemporaneous with the solution of the limestone.

Calcium carbonate deposits in caves include dripstone and horizontally banded travertine and calcareous tufa. Such travertine and tufa deposits are exposed in the road cut near the west quarter corner of sec. 28, T. 4 N., R. 13 E. The dripstone is best observed in the large cave near Cave City, where it consists of stalactites, stalagmites, and massive sheet-like deposits on the walls.

Origin of the Calaveras Formation, and Relations With the Green Schist Sequence. Sediments from which the schists of the Calaveras formation were formed probably accumulated slowly in undisturbed water. The presence of graphite indicates that organic material was preserved in the original sediments, an effect generally attributed to an oxygen-poor condition of the water. The probable fine-grained character and thin bedding of the sediments are consistent with the concept of deposition in quiet water. The monotonous succession of alternating graphitic schist and quartzite indicates that, except for periods of limestone deposition, conditions of deposition varied little.

The original nature of the material now represented by quartzite is of importance in considering the origin of the Calaveras formation. There seems to be little reason to doubt that the sediments were originally fine-grained, but evidence as to whether the premetamorphic siliceous material was chert or quartz siltstone is inconclusive. If there were minute inclusions of carbonate in the quartz grains, their presence would suggest that at least part of the silica had replaced limestone; but such inclusions are not present. Quartzite of the Calaveras formation is similar in some respects to the Homer quartzite (Durrell, 1940, pp. 32-36) believed by Durrell to be derived from chert. Points of similarity between the two rocks are fine grain size, granoblastic texture, and graphitic partings between quartzite layers. The quartzites of the Calaveras formation are different from the Homer quartzite as described by Durrell in that they contain little or no feldspar, and some layers show a gradation from coarse to fine that suggests relict clastic texture.

In this area the limestone apparently is derived from lime mud rather than lime sand. As with the schists, the presence of graphite suggests that the limestone was deposited in oxygen-poor water, whereas the lime sands are commonly associated with a well-aerated environment. The absence of oolites and clastic quartz grains of sand size, common features of lime sands, provides additional support for the hypothesis that these rocks are derived from lime muds.

The green schist sequence, designated by earlier writers as amphibolite schist, was separated from the Calaveras formation in the gold belt folios (Turner, 1894; Ransome, 1900) because of the marked contrast in lithology. However, the age relations of the two units were but imperfectly understood. Ransome (1900) pointed out that the rocks of the green schist sequence are "irregularly involved" with the Calaveras formation and considered them to be about the same age. On his map, however, the green schist is indicated as "Carboniferous or Juratrias." Knopf (1929, p. 12) found the green schist and Calaveras formation lithologic types to be interbedded in several mines and concluded that the green schist is "of Calaveras age, presumably Carboniferous." In recent work of the U. S. Geological Survey (Eric et al., 1954) some of the rocks previously included with the amphibolite schist were removed from this group and correlated with the Logtown Ridge formation, but the age of other parts of the sequence was not determined.

The geologic map of the Jackson quadrangle, California (Turner, 1894) shows large areas in which the green schist sequence is not interlayered with other rocks. This distribution suggests that a large part, at least, of the green schist sequence is separate from the Calaveras formation and not intimately interbedded with it. Graded bedding in rocks of the green schist sequence in the Calaveritas quadrangle suggests that these rocks underlie the Calaveras formation. Further evidence is needed to determine whether the green schist sequence is of Mississippian age or older. The relations found in this quadrangle are not necessarily valid elsewhere because neither the Calaveras formation nor the green schist sequence (amphibolite schist of the early writers) has been closely defined as to age or lithologic

type. Consequently both units may include rocks of diverse age.

Except in the southeast part of the quadrangle, the contact between the green schist sequence and the Calaveras formation appears to be transitional. In the southeast part of the quadrangle, at the contact between the two formations, fragmental rocks, probably conglomerates, suggest the presence of an unconformity that may be local. The porphyroblastic actinolite schist of the green schist sequence is separated in many places from the interbedded quartzite and graphitic schist of the Calaveras formation by a zone about 150 feet thick of interbedded black and yellow-green phyllite. In the absence of a completely exposed section that might show a definite break in deposition, the contact has been drawn arbitrarily at the base of the lowermost bed of black phyllite. Descriptions of the contact zone at three representative localities are given in the following paragraphs.

In the west central part of sec. 35, T. 4 N., R. 12 E., 200 feet from the boundary of the quadrangle, the transition zone is exposed in a small north-trending gully. Typical graphitic schist and interbedded quartzite of the Calaveras formation are exposed in the bottom of the small valley (see pl. 1), and thick-bedded porphyroblastic green schist is poorly exposed on the gentle north-facing slope of the valley. The transition zone is about 150 feet thick and consists of alternating beds, 2 to 5 feet thick, of yellow-green phyllite and dark-gray to black phyllite. The yellow-green phyllite of this zone is similar to phyllite interbedded with the porphyroblastic green schist. Graphite has not been identified in the black phyllites of this zone. Quartzite is present in thin laminae in some of the black phyllite and becomes increasingly abundant toward the black schist of the Calaveras.

Probably the most significant exposures are those in the north parts of secs. 32 and 33, T. 4 N., R. 13 E. At several localities sets of graded beds are exposed in the ditches besides the roads; these localities are indicated on the geologic map (pl. 1) by symbols showing the direction of tops of beds. The graded beds are in the upper part of the porphyroblastic green schist. They show that the tops of beds are in the direction of the Calaveras formation, and therefore suggest that the green schist sequence underlies the Calaveras formation. At each locality several graded beds are present, each consisting of a well-graded unit showing a poorly defined upper contact and a sharp contact with the underlying argillaceous bed. The transition zone is exposed in road cuts in the vicinity of the northeast corner of sec. 32, T. 4 N., R. 13 E.

In the road cut of Ponderosa Way in the SW¼SW¼ sec. 35, T. 4 N., R. 13 E., a fragmental rock, probably a stretched conglomerate, lies in a zone between typical rocks of the green schist sequence and typical graphitic schist of the Calaveras formation. The fragmental rock consists of pebbles and granules of fine-grained green schist, together with pebbles of black phyllite, in a matrix of black schist. The fragments of fine-grained green schist resemble parts of the green schist sequence. This fragmental rock may be a basal conglomerate of the Calaveras formation. The zone in which fine-grained black schist and yellow-green schist are interbedded is absent in this vicinity.

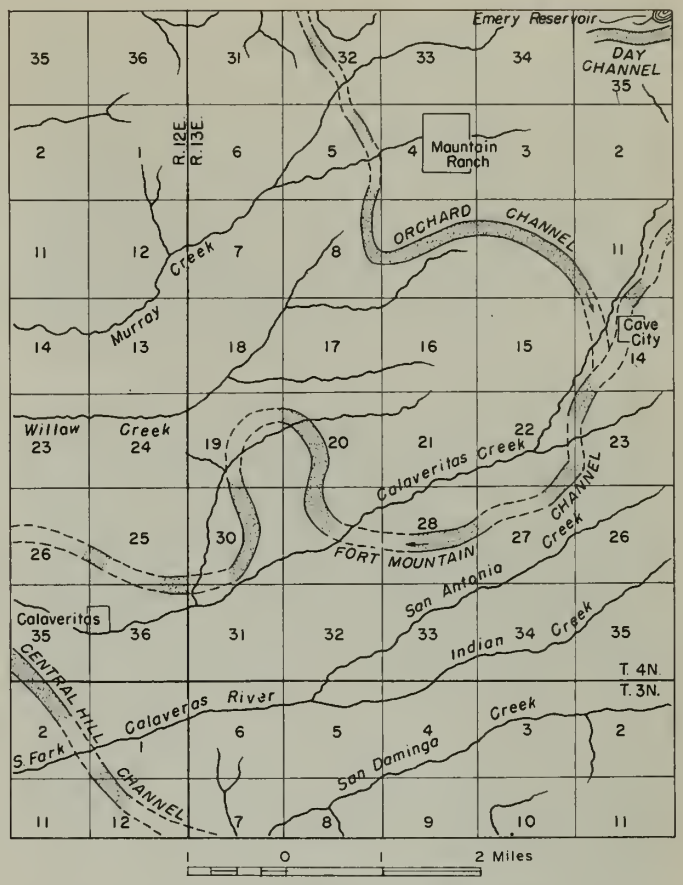


FIGURE 3. Map showing courses of early Tertiary streams in the Calaveritas quadrangle. After Crawford and Storms (1894)—Mountain Ranch called Eldorado on original.

Tertiary Gravels and Rhyolite Tuffs

Coarse auriferous stream gravels and rhyolite tuffs of early Tertiary age unconformably overlie the deformed pre-Tertiary rocks. The gravels are widely but sparsely distributed in the Calaveritas quadrangle, whereas the tuffs, which overlie most of the gravel, occur chiefly in the northeastern part of the quadrangle. Most deposits of gravel and tuff are on the crests or flanks of ridges, well above the present streams.

In general, nontuffaceous gravels rest on bedrock and are overlain by gravels containing interbedded lenses of rhyolite tuff. The proportion of tuff increases upward in the section and gravels are rare in the uppermost beds. Locally, beds consisting wholly or partly of tuff rest directly on bedrock, overlapping the nontuffaceous gravels that occupy the lower part of the ancient valleys in which these rocks were deposited.

The lower Tertiary deposits were not studied in detail during the present investigation. However, the deposits are shown on maps prepared by Crawford and Storms (Storms, 1894, p. 482) and by Lindgren (1911, pl. 1). Part of the map by Crawford and Storms is reproduced here (fig. 3) to show the courses of the streams in which the gravels were deposited.

Gravels. The gravels are very coarse, and boulders more than 2 feet in diameter are common in many deposits. The coarseness of the material and the chaotic

structure and steep walls of some of the deposits indicate that the deposits were formed by fast-flowing streams in steep-sided valleys.

The gold in most of the gravels was probably derived from lode deposits in the so-called Pocket vein belt east of the Mother Lode. The large size of some of the boulders and the angularity of many of the pebbles in the auriferous gravels indicate that they have traveled but short distances. Most of the pebbles are composed of rock types found within the quadrangle and in areas lying to the north and east—mainly graphitic schist, quartzite, and vein quartz. Pebbles of granitic rocks, presumably from sources east or north of the quadrangle, are less common; pebbles of rock types common along the Mother Lode are absent.

The Hidden Cave and Cotton Flat placer mines are developed in small valleys underlain by limestone in the northeastern part of the quadrangle. The valleys are apparently solution valleys, inasmuch as the bedrock floors are lower in altitude than the bedrock of the present outlet for surface drainage. Water-laid rhyolite tuff is present in the valleys and is overlain by washed gravels. It is not clear whether these gravels were deposited in this position during early Tertiary time or whether they are merely waste from placer operations in the higher gravels in this vicinity. The existence of auriferous gravel under the tuff is suggested by the presence of a drainage tunnel at the lower end of Cotton Flat, cut through rhyolite tuff about 15 feet below the surface. Presumably the tunnel was dug to drain the water from saturated gravels that lay below the altitude of the surface drainage from the valley.

Gravels of the Central Hill channel exposed in the Railroad Hill, Calaveritas Hill, and Ritchie Hill mines are different from other gravels in the quadrangle in that they contain pebbles of reddish-purple andesite. These deposits are thought to be much younger than the gravels described previously, because the andesite pebbles were apparently derived from the Mehrten formation, which overlies the rhyolite tuff.

Rhyolite Tuff. The lowermost rhyolite tuff in the section forms discontinuous lenses interbedded with the gravels. The lenses vary greatly in length and thickness. The tuff is white, poorly indurated, and bedded; mixtures of various proportions of gravel and tuff are common. Pebbles of tuff in the interbedded gravels testify to the reworking of some of the tuff. The lenticular tuff is most abundant in the northeast part of the quadrangle but is found as far southwest as the Oro Fino hydraulic mine. Tuff lenses are absent in the deposits of the Central Hill channel.

The most complete section of rhyolite tuff is in the northeast corner of the quadrangle, where the tuff rests at least locally on thin gravels. This section is apparently above the zone in which the lenticular deposits are found. From bottom to top the tuff section consists of: (1) light-red, massive indurated tuff, with columnar jointing; (2) non-indurated clay, or ash, and bedded, poorly sorted tuff with interbedded gravels; and (3) a jointed layer of white indurated tuff similar to the lower except in color. The two indurated layers with columnar jointing are welded tuffs or ignimbrites, and the intermediate bedded material is not welded. The lower welded tuff layer shows a dip of about 15° in a road-cut exposure; this is apparently an initial dip resulting from deposition of this layer on a steeply sloping surface. Both the bedded tuff and the upper welded tuff lie flat, or nearly so.

The welded tuffs are porous and consequently have a low density. The upper welded tuff shows a weak flat-lying planar structure that is a result of the parallel arrangement of tabular rock fragments and shards. The welded tuffs consist of crystal and rock fragments in a fine-grained matrix; the fragments comprise about 25 percent of the rock. The welded tuffs are poorly sorted—most of the crystal fragments are 0.5 to 3 mm in diameter and most of the rock fragments are 5 to 25 mm in diameter. Crystal fragments include quartz, orthoclase, sanidine, and sodic plagioclase. Pumice is the most abundant kind of rock fragment, but obsidian and rhyolite are common.

In thin section the matrix is seen to consist of glass shards in a groundmass of structureless glass, with a texture similar to that of some of the Bishop tuff described by Gilbert (1938). Opal, tridymite, and cristobalite are present in the cavities, and some shards are tridymite. The glass of the upper layer is in part devitrified, and possibly tridymite and sanidine were formed, as in the Bishop tuff.

Age and Correlation. The gravels and tuffs are of uncertain age, but they probably fall within the Eocene to Pliocene interval. The gravel underlying the rhyolite tuff is considered by Allen (1929) and MacGinitie (1941) to be correlative with the Ione formation, of Eocene age. On the other hand, some of the gravel in the Central Hill channel is much younger and postdates at least part of the Mehrten formation. The Mehrten formation is believed by Piper, Gale, Thomas, and Robinson (1939, pp. 69-71) to be partly of Miocene age—probably late Miocene—and perhaps partly of early Pliocene age.

Strata consisting of gravel interbedded with rhyolite tuff and strata of rhyolite tuff alone are correlated with the Valley Springs formation as defined by Piper and others (1939, pp. 71-72). Although welded tuffs have not previously been recognized in the Mother Lode region, those in the northeast corner of the Calaveritas quadrangle are apparently remnants of more extensive deposits belonging to the Valley Springs formation. Two layers of indurated rhyolite tuff in the type section of the Valley Springs formation, described by Piper and others (1939, pp. 71-73), show columnar jointing and are probably welded tuffs. A welded tuff forms the upper part of a rhyolite tuff sequence, present in the Angels Camp quadrangle, that is correlated by Eric and others (1954) with the Valley Springs formation. Gale (Piper et al., 1939, pp. 79-80) tentatively correlates the Valley Springs formation with the Salinas shale, of middle Miocene age.

The proportion of rhyolite tuff to gravel in the deposits of this quadrangle increases gradually upward, so that the uppermost beds are almost entirely tuff. This relation suggests that the tuff is conformable on the gravel, but is incompatible with the concept that the gravel is of Eocene age and the tuff of Miocene age. The Eocene age of the gravel that underlies the tuff seems well established; the tuff may be in part Oligocene, or an unrecognized unconformity may exist beneath the lowest tuff unit. In torrentially bedded material such as the

gravel, in which minor intraformational breaks are common, such an unconformity might easily escape notice.

ntrusive and Metaintrusive Rocks

Intrusive and metaintrusive rocks present in the Calaveritas quadrangle include granodiorite, ultramafic rocks, hornblende gabbro, and diorite.

The largest mass of granodiorite, in the west-central part of the quadrangle, is part of a large mass that extends into the adjoining quadrangle. Several smaller pod-shaped masses are sparsely distributed in the area. In general the granodiorite is deeply weathered and very poorly exposed.

The central part of the large intrusive is a homogeneous, coarse-grained rock that consists of quartz, plagioclase, orthoclase, muscovite, and biotite. The rock resembles parts of the main Sierra Nevada batholith. The smaller masses of granitic rocks are composed mainly of quartz, feldspar, and muscovite. They have not been studied in detail and may differ somewhat in composition from the large mass and from one another.

Hornblende gabbro, consisting largely of hornblende and plagioclase, and hybrid rocks intermediate in composition between the hornblende gabbro and granodiorite are abundant in the marginal part of the main mass of granodiorite; several small masses are enclosed in schist southeast of Mountain Ranch. The hornblende gabbro and hybrid rock masses enclosed in schist have been differentiated on the map, but because of the poor exposures and complex relations between rock types those associated with the large granodiorite intrusive were not differentiated from the granodiorite.

Most of the ultramafic masses are thin sheet-like intrusions that parallel the foliation of the schist, although a few masses are more nearly equidimensional. The intrusives are metamorphosed, and consist largely of talc, but antigorite rock is abundant locally.

Massive diorite is present as dikes that were emplaced along joints in the schists of the Calaveras formation. The dikes range in thickness from a few inches to about 5 feet and are too small to be shown on the map. The diorite is a dark-gray, fine-grained rock that in some places contains phenocrysts of hornblende and feldspar. Many dikes show banding parallel to the margins, owing to variation in grain size and perhaps in part to variation in composition.

The granodiorite and ultramafic masses of the Calaveritas quadrangle have been indicated on the map (pl. 1) as being of Jurassic(?) age. The hornblende gabbro and hybrid rocks are probably about contemporaneous with the granodiorite. The evidence available in the quadrangle does not permit an age assignment closer than post-Calaveras (Mississippian?) and pre-Eocene. According to Hinds (1934, p. 192) the intrusive rocks of the Sierra Nevada appear to be of Jurassic age.

Although the granodiorite and ultramafic masses are younger than the period of major deformation, they are older than a subsequent but undated period that resulted in the widespread development of slip cleavage. The strike and dip of the slip cleavage is in general parallel to the quartz veins of the Mother Lode system, suggesting that the slip cleavage is genetically related to the faults that controlled the formation of the Mother Lode quartz veins. Much of the talc is schistose, and a secondary planar structure resulting from shearing is evident in the small masses of granodiorite. Secondary planar structure is not apparent in the granodiorite of the large mass, but the mineral grains are extensively fractured. These features of the ultramafic and granodiorite masses were presumably developed by movements that resulted in the formation of the slip cleavage.

Although all other units of the bedrock complex are sheared, the diorite is massive and shows no evidence of shearing. The diorite therefore was probably intruded after the slip cleavage had developed and is the youngest intrusive rock in the area.

Structure

Interpretation of the geologic structure is exceptionally difficult because of the complexity of the area, widespread destruction of bedding by shearing, scarcity of outcrops, and the absence of key horizons in the schist that underlies most of the quadrangle. The expenditure of time and effort that would be required to gain a thorough understanding of the structure seems disproportionately large and certainly is not warranted until other areas more likely to yield fundamental concepts have been exhaustively studied. Because of the inadequacy of the data obtained by customary field procedures, interpretation of geologic structure on the map has been held to a minimum.

Major Structures. The metamorphic rocks of the Calaveritas quadrangle are schistose and probably complexly folded. High-angle faults are probably important structural elements in the quadrangle, also; but except for short segments of faults that truncate limestone masses, it has been impossible to delineate the faults with a reasonable degree of certainty or even to prove their existence.

Three kinds of evidence suggest, although none is conclusive, that the rocks of the Calaveras formation are repeated by folding: (1) the great apparent thickness of the formation, (2) local minor folds, and (3) schistosity. The great apparent thickness of the Calaveras formation, which was derived from sediments that evidently accumulated slowly, suggests repetition of the beds. Small, tight isoclinal folds in thin-bedded quartzite are well exposed in a road cut about a quarter of a mile northeast of Mountain Ranch; other minor folds, while not abundant, are well distributed in the quadrangle. These suggest the presence of larger folds. Schistosity is commonly associated with folding, and any mass of schistose rocks must be suspected of being folded, unless it has been proved otherwise.

The largest mass of green schist lies within the area where bedding and cleavage strike east, in the southern part of the quadrangle. If the interpretation is valid that the green schist sequence underlies the Calaveras formation, the green schist forms the core of a complex major anticline. Complexity of the fold is indicated by outliers of black schist whose outcrop pattern suggests that they are infolded with the green schist. Axes of the minor folds involving the outliers of black schist apparently plunge in opposite directions at the east and west ends—the axes of these minor folds as well as the axis of the major fold are probably undulating.

The trend of the schistosity in the northern part of the quadrangle is northwest, parallel to the broad regional

trend of the western Sierra metamorphic belt. In the southern part of the quadrangle the trend of the schistosity and bedding is west. To the north and south the westerly trend is transitional into the more general northwest trend; but locally, near the west boundary of the quadrangle, the change in trend is abrupt, with an acute angle of about 40° between the two directions. Exposures in the southern part of sec. 2, T. 3 N., R. 12 E., in the narrow zone between the area of northwest strike and the area of east strike, suggest that the change is accomplished by folding and crumpling; but the exposures are not closely enough spaced to eliminate the possibility of a major fault in this zone.

Along the ridge north of Esmeralda the presence of an economically important fault or sheer zone that provided a favorable situation for the migration and deposition of ore-forming materials is suggested by the group of mines on the ridge. The mines are reported to be developed on quartz veins that strike about N. 80° W., parallel to the bedding and foliation in this vicinity. Another major fault or shear zone extending from sec. 31, T. 5 N., R. 13 E., to the vicinity of the mine in the SE¼SE¼ sec. 23, T. 4 N., R. 13 E., is suggested by the converging pattern of the schistosity along a line joining these points as well as by the strong shearing near the mine. Further evidence of faulting or strong shearing in these zones is afforded by the swarms of ultramafic masses. The association of elongate masses of metamorphosed ultramafic rock with major fault or shear zones has been shown by Stromquist's mapping (in preparation) in the northwest quarter of the San Andreas 15-minute quadrangle and by the current work of the writer and D. B. Tatlock in the southwest quarter of the San Andreas 15-minute quadrangle.

The presence of limestone in the Calaveras formation north of the main mass of green schist but not south of it suggests that the horizons of the Calaveras formation in contact with the green schist on the north and south sides are different; if so, it suggests that faulting has played a part in the development of the postulated anticlinal structure.

Planar and Linear Structures. In addition to bedding, two other kinds of planar structures have been recognized—schistosity and slip cleavage. Schistosity is the dominant planar structure in most places throughout the quadrangle, and is developed both in the green schist sequence and in rocks of the Calaveras formation. The alinement of tabular minerals and rock fragments in a parallel arrangement resulting from mechanical rotation as well as from recrystallization is responsible for the schistosity.

Slip cleavage (White, 1949) consists of closely spaced microfaults and crinkles (figs. 4 and 5). The slip cleavage consistently strikes northwest and dips steeply northeast approximately parallel to the Mother Lode vein system. The slip cleavage is well developed in the southwest part of the quadrangle where its attitude makes a large angle with that of schistosity; it becomes less evident toward the northwest, where it is nearly parallel with the schistosity. Directions of offset on slip cleavage planes are not consistent, and slip folds are a common feature. Development of such folds has resulted in shortening of the section in a direction normal to the cleavage.

In the deformed rocks, bedding is best preserved in rocks of the green schist sequence. In schists of the Calaveras formation, although the bedding generally cannot be identified, it is well preserved in a few places where it is parallel to the schistosity and in scattered small areas where minor folds bring the bedding across the schistosity. Bedding is preserved in some of the fine-grained, probably argillaceous limestones; in the coarse-grained limestone the bedding has been destroyed. Color banding,

FIGURE 4. Bedding offset on slip cleavage planes. Schistosity is parallel to the bedding. (*Drawing by Esther McDermott from polished specimen.*)

Figure 5. Slip cleavage and related folds in Calaveras formation, Indian Creek, near west boundary of sec. 33, T. 4. N., R. 13 E. Banded rock at top is interlaminated graphitic schist and quartzite. Light-gray rock below is chlorite schist. Oak leaves in photograph are about 2 inches long.

caused by streaks of black graphite-rich material, is common in the coarse-grained limestone; in most places it probably is parallel to the bedding, because it is parallel to contacts with the schist wall rock and to thin layers of schist interbedded with the limestone.

Shearing on planes of schistosity has been sufficient in many places to destroy the original bedding of the rocks of the Calaveras formation. It is conceivable that shearing on the schistosity planes has in some places developed into faulting that might be related either to the strain that caused the development of most of the schistosity or to a later strain.

Joints have been mapped only where they are prominent. They have provided avenues for the intrusion of thin diorite dikes and at least locally have controlled the courses of streams.

Several different kinds of lineation have been indicated on the map by a single symbol; these are (1) elongate fragments of quartzite (largely in tectonic breccia), (2) stretched conglomerate pebbles, (3) elongate tabular aggregates of mica, and (4) the intersection of bedding and schistosity. By far the most common and widespread type of lineation is that of the elongate quartzite fragments—other types are present only locally. With the possible exception of the stretched conglomerate pebbles, the mapped lineations are probably parallel to the *b* tectonic axis. The intersection of the slip cleavage and schistosity directions is marked by crenulations in the schistosity plane. Attitudes of the crenulations were mapped in the field but are not shown on the final map because of their random orientation. Axes of minor slip folds genetically related to the slip cleavage were not mapped nor were lineations of uncertain classification.

The axes of the minor folds indicated on the map are in the plane of the schistosity rather than that of the slip cleavage and are apparently related to the period of deformation that caused most of the major structures. The long axes of the elongate tectonic breccia fragments are parallel to the axes of minor folds where the two are found together, indicating the probability that the tectonic breccia lineation is parallel to the *b* tectonic axis. With few exceptions, the mapped lineations plunge east and southeast at moderate angles, suggesting that any major folds that are present have a similar plunge. In small areas in the southern part of sec. 24, T. 4 N., R. 12 E., and near the southeastern corner of the quadrangle the plunge is north of west.

Determination of the kind of deformation causing elongation of the conglomerate pebbles would help to orient them with regard to tectonic axes. However, it is not clear whether the pebbles have been rolled about the *b* axis or dragged out parallel to *a*. Tension cracks normal to the long axes of the pebbles are absent, as are features indicative of rotary movement. Pebble surfaces are not slickensided.

If the stretched conglomerate pebbles in the southeast part of the quadrangle are parallel to the *b* tectonic axis, their westerly plunge appears inconsistent with the hypothesis that the main mass of green schist forms the core of an eastward-plunging anticline. However, the angle of plunge of the long axes of the pebbles is only about 5 degrees, and it is not unlikely that the axis of the major fold is undulating and in general may be nearly horizontal.

ECONOMIC GEOLOGY

Although gold is historically the most important mineral commodity in this quadrangle, as it is elsewhere in the Mother Lode region, there has been little activity in gold mining in recent years, and limestone is now economically the most important mineral product in the quadrangle. Other mineral products exploited in the past include minor amounts of chromite and possibly copper. The chief purpose of the present investigation was to study the limestone deposits; consequently these deposits have been studied in considerable detail. Building materials present, in addition to limestone, include pozzolana, amphibole asbestos, and talc, but they are at present economically unimportant. Metallic deposits have received relatively less attention herein.

Limestone

Factors contributing to the value of a limestone deposit include large size, low magnesia content, and the absence of caves or filled caves. The analyses in table 3 illustrate part of the range in composition of limestones in the Calaveritas quadrangle; no attempt has been made to collect for analysis material with the highest and with the lowest magnesia content.

The value of a deposit is decreased by broken ground and contaminated rock that has resulted from the slumping of overlying rock into places from which limestone was removed by solution. In some places the slumped material consists merely of broken limestone; in other places, however, it consists of blocks of limestone and schist mixed with the clay and stream gravels that partly filled the caves. Mud from the filled caves is sticky and if mixed with rock fed to the mill causes trouble in grinding.

With the exception of the deposit at quarry No. 4, limestones exposed in the quadrangle dip steeply. The steep dips suggest that at least some of the longer masses extend to a considerable depth. However, no evidence is

Table 3. Analyses of limestones in Calaveritas quadrangle.

	a	b	c	d	e
SiO_2	0.65	0.08	0.49	0.20	0.53
Fe_2O_3	0.08	Trace	0.36	0.16	0.16
Al_2O_3	0.22	0.08	0.63	0.22	0.25
$CaCO_3$	88.10	78.80	82.70	98.00	97.50
$MgCO_3$	10.70	20.92	15.80	1.32	1.52
Na_2O	0.02	0.02	0.03	0.02	0.02
K_2O	0.05	0.03	0.03	0.02	0.02
Total	99.82	99.93	100.04	99.94	100.00
Recalculated: as oxides					
SiO_2	0.65	0.08	0.49	0.20	0.53
Fe_2O_3	0.08	Trace	0.36	0.16	0.16
Al_2O_3	0.22	0.08	0.63	0.22	0.25
CaO	49.21	44.08	46.32	54.83	54.65
MgO	5.08	9.99	7.52	0.63	0.72
CO_2	44.51	45.65	44.66	43.86	43.65
Na_2O	0.02	0.02	0.03	0.02	0.02
K_2O	0.05	0.03	0.03	0.02	0.02
Total	99.82	99.93	100.04	99.94	100.00

Analyses by Calaveras Cement Co.

All samples are chip samples from the surface.
a. Represents 50 feet across strike, in SE¼SW¼ sec. 3, T. 4 N., R. 13 E.
b. Represents 350 feet across strike in NW¼NE¼ sec. 10, T. 4 N., R. 13 E.
c. Represents 700 feet across strike, in NW¼SW¼ sec. 11, T. 4 N., R. 13 E.
d. Represents 100 feet across strike, in SE¼SW¼ sec. 11, T. 4 N., R. 13 E.
e. Represents 80 feet across strike, in SW¼NW¼ sec. 28, T. 4 N., R. 13 E.

FIGURE 6. Quarry No. 4, Calaveras Cement Co., looking west. *Aerial photograph by T. C. Slater, Calaveras Cement Co.*

available to indicate reliably the depth to which a deposit might extend; it may lens out abruptly or it may be faulted off at any distance below the surface. Similarly, the complex relations between low-magnesia limestone and high-magnesia limestone make unsafe any prediction of the quality of the limestone at depth. Diamond drilling will therefore be necessary to determine the size and quality of any particular limestone mass.

Quarry No. 4, Calaveras Cement Co. Quarry No. 4 of the Calaveras Cement Co. (fig. 6) is on Old Gulch, a mile northwest of the village of Calaveritas. The quarry currently supplies the company's cement plant at Kentucky House, 5½ miles west of the quarry and 2 miles south of San Andreas, with both limestone and the schist that is used in place of shale in the manufacture of cement. Rock is hauled by trucks operating on a company-owned road from the quarry to the plant. Quarrying began in 1935 and since then has been essentially continuous.

The limestone at quarry No. 4 is the northernmost of two large masses present in a tongue of the Calaveras formation that extends westward between the large granodiorite intrusive and the main area of green schist. At the surface both limestone masses are surrounded by black graphitic schist and quartzite; the presence of a connection at depth is purely speculative.

Rocks exposed at the quarry are divided into three blocks by two high-angle faults, which in most places make a large angle with the strike of the beds. The largest mass of limestone is in the central block, between the two faults. The structure of the central block is thought to be an open syncline that plunges northeast, as suggested by the trace of the footwall contact of the limestone on horizontal benches in the quarry. This interpretation appears compatible with geologic data that became available in 1950. Other workers at an earlier stage in the development of the quarry considered the structure to be a tightly folded north-plunging syncline overturned to the west. According to their interpretation the two faults shown on the map (pl. 2) do not exist, or are of minor importance. If we accept their interpretation, we must consider the limestone in the north extension of the quarry as continuous with the other limestone in the quarry, and a massive quartz-amphibole rock and schist west of this limestone as forming the core of the syncline. This hypothesis fails to explain the lack of continuity of the limestone on the northeast corner of the quarry and the absence of other evidence of repetition of beds on the two sides of the fold.

The presence of a fault at the north side of the quarry is indicated by the following evidence: (1) the trend of the contact between the schist and the quartz-amphibole rock north of the limestone is nearly normal to the traces of bedding in the rocks in the north wall of the quarry; (2) the layer of quartz-amphibole rock is truncated at the limestone contact; and (3) a slickensided surface, presumably a fault plane, was present at the time of the present study in the north wall of the intermediate level of the quarry.

The wall was too dangerous to approach closely, but the strike of the surface was parallel to the fault indicated on the map and the dip was about 60° N. The slickensides plunged east at a moderate angle, but it could not be determined whether the angle of plunge was greater or less than the dip of the beds. Without this information the amount and direction of the relative movement of the two blocks cannot be calculated, even though the limestone in the north extension of the quarry is assumed to be an offset segment of the bed in the central block. In view of the fact that the slickensides on the fault plane plunged in the same direction as the dip of the beds, the total displacement is much greater than the apparent horizontal displacement of the limestone bed.

The presence of the southermost fault is indicated by the contact between limestone and schist, which truncates the limestone at a large angle to the strike. The position of the fault is marked in the small cut east of Old Gulch near the south end of the quarry by a narrow zone of gray clay enclosing limestone blocks. The fault is assumed to dip south because the limestone in diamond drill holes 16, 19, and 23 falls on the projection of the limestone in the quarry, showing no evidence of displacement. A movement of more than 1,000 feet on this fault is suggested by the absence of a limestone bed on the south side of the fault that can be correlated with the limestone in the quarry.

The structure of the limestone in the north block may be more complicated than is indicated on the map, and the limestone may be cut by several high-angle faults with small displacements. If such minor faults exist, they are concealed by slumping that resulted from solution of part of the limestone.

In the central block a thick limestone unit which has supplied most past production is underlain by the footwall strata and overlain by the hanging wall schist. The limestone is white to dark gray, coarsely crystalline throughout, and massive. No fine-grained dolomitic limestone was exposed in 1950. The limestone contains a few thin lenses of dull black graphitic schist, but these constitute only a small proportion of the mass. The limestone bed ranges from 300 to 400 feet in thickness, probably owing to local thickening during deformation.

The footwall strata are exposed in the west and south walls of the quarry and have been penetrated a short distance by diamond-drill holes. At the west side of the quarry the main limestone bed is immediately underlain by interbedded limestone and graphitic schist; individual beds range in thickness from a few inches to as much as 4 feet. Chlorite schist of undetermined thickness is in contact with the limestone at the south wall of the quarry, and also, according to diamond-drilling records, beneath the quarry pit. South of the quarry the chlorite schist gives way to light-colored siliceous mica schist. The interbedded graphitic schist and limestone of the west wall are underlain by graphitic schist and quartzite. East of the quarry the limestone is overlain by strata of thin-bedded graphitic schist and quartzite with rare small pods of limestone.

The limestone exposed in the north extension of the quarry, in the north block, is similar in lithology to that in the central block but contains more interbedded schist. Bedrock is not exposed east of this limestone.

The strata of the north block exposed in the quarry walls west of the limestone consist mainly of two thick units of deeply weathered micaceous graphitic schist separated by a massive unit about 100 feet thick consist-

ing of fine-grained black quartz-amphibole rock. This rock may have been formed by replacement of a limestone bed—it contains numerous pods, less than an inch to about 3 inches long, of coarse crystalline marble.

Diorite dikes cut the limestone and associated rocks. Although none were exposed in the quarry openings at the time of mapping, dikes have been penetrated by several diamond-drill borings and are exposed in a few places on the hill east of the quarry. The rare small exposures and the diamond-drill holes did not provide enough control to permit differentiation of the dikes from the other rocks in the maps and sections.

Cave City Deposit. Because of its large size the limestone deposit that underlies Cave City and Mountain Ranch is of considerable economic interest. This mass contains little interbedded schist, but much of the limestone is dolomitic. Consequently, the value of the deposit depends largely on the size and shape of the parts of the deposit that are of sufficient purity to process.

Several open caves were observed at the surface of this limestone mass, and it is probable that there are unknown caves that do not reach the surface. The depressions in which the Cotton Flat and Hidden Valley mines are located probably owe their origin in part to solution. If so, the limestone under the tuffs and gravels in these depressions possibly contains much broken and contaminated rock, similar to that encountered in parts of quarry No. 4.

Other Deposits. The limestone in the north part of sec. 35, T. 4 N., R. 13 E., is fine-grained and thin-bedded and may contain some silt or clay. The mass is poorly exposed, but no interbedded schists were noted. The limestone is extensively replaced by ferruginous chert.

The limestone mass in the west-central part of sec. 28, T. 4 N., R. 13 E., is a coarse-grained rock, at least some of which is low in magnesia (see e, table 3). Near the northeast margin of the limestone is a dolomite zone 10 to 20 feet thick that locally contains abundant tremolite. In the stream bottom in the north side of the limestone a zone a few feet thick is mineralized, containing vein quartz, tourmaline, and disseminated sulfide crystals. In the road cut are exposed small masses of travertine and calcareous tufa, apparently deposited in former caves in the limestone. The limestone is very poorly exposed and has not been studied in detail.

The limestone mass in the north part of sec. 31, T. 4 N., R. 13 E., underlying an area of about 2,000,000 square feet, is similar in lithology to that at quarry No. 4. Boundaries of the limestone were located with reasonable accuracy west of Calaveritas Creek, but were not accurately located east of the creek. The west end of this mass is 300 feet and the east end about 400 feet above exposures near the creek bed, indicating that the deposit extends to a depth sufficient to warrant exploration, provided that the quality of the limestone is satisfactory. The deposit contains interbedded schists, but the number and thickness of the schist beds could not be determined from the natural exposures. The economic value of the deposit might well depend on the amount and distribution of the interbedded schist.

Pozzolana

The welded rhyolite tuff near the northeast corner of the quadrangle might be a possible source of pozzolana. However, this material is not likely to be exploited until the large deposits of similar material available in nearby areas outside the quadrangle at lower altitudes and closer to transportation facilities have been exhausted. Opal, not of gem quality, present in some of the talc masses and in some of the chert that replaces limestone might also conceivably be used as pozzolana.

Amphibole Asbestos

Thin slip-fiber veins and veinlets of amphibole asbestos, probably tremolite or actinolite, are common in the ultramafic masses, but most are too small to be of economic interest. The largest amphibole vein observed is about 200 feet west of the triangulation station in the SW¼ sec. 1, T. 3 N., R. 13 E. This vein is about a foot thick and has been explored by means of a short tunnel. Fibers of the amphibole are nearly parallel to the walls, and the length of the fibers is not related to the thickness of the seam. In hand specimens the apparent length of the fibers is commonly more than 2 inches. No published record of production from this deposit was found.

Chrysotile veinlets with a maximum thickness of about 1 mm are present in serpentine in a small area on the northeast side of the ridge in the south half of the NE¼ sec. 2, T. 4 N., R. 13 E.

Talc

Talc forms large masses in this quadrangle, but impurities such as red iron oxide, pyrite, antigorite, and ankerite are abundant. Much of the talc is strongly foliated. Masses of massive dark-green talc are rare and those observed contain no more than a few hundred tons. Specimens of high-grade talc are reported to have been collected from the Wheelock gold mine (Thomas Brothers group).

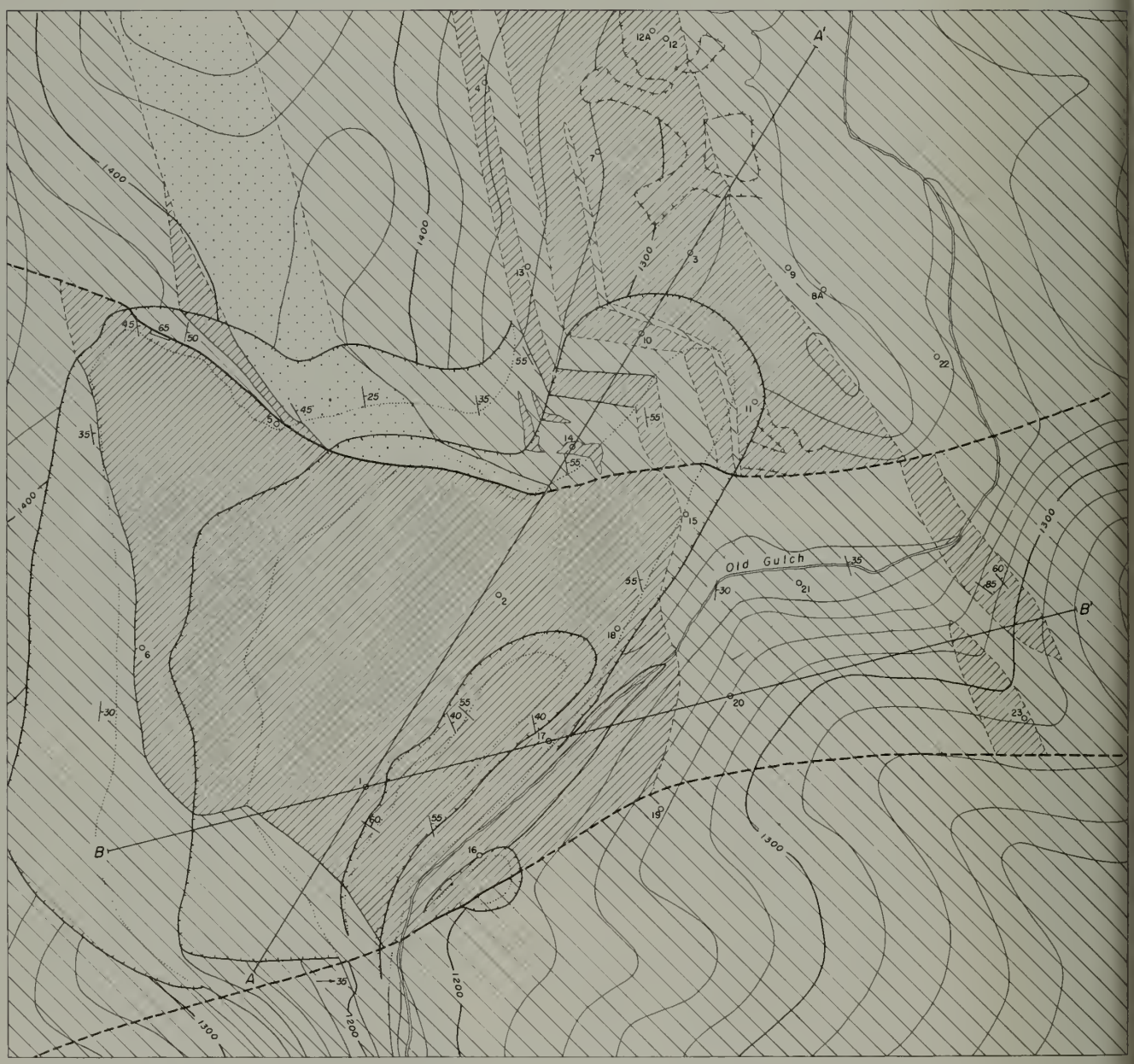
In the past, small amounts of talc from Calaveritas quadrangle have been used locally for refractory furnace linings and for building stone, but none has been mined for many years.

Gold

In the Calaveritas quadrangle, gold has been produced from placer operations in the beds of the present streams, from hydraulic and drift mines in the elevated gravel deposits of the early Tertiary streams, and from lode deposits. The history of gold mining in this area is similar to that of other places in the Mother Lode region and is adequately treated in other publications. There is little basis for evaluation of the gold deposits, for production records were not kept until 1894, long after the period of maximum activity, and those kept since 1894 are incomplete. Current activity is limited to part-time operations, largely exploratory, by less than a score of men using meager equipment.

Dredge tailings on the larger streams of the area and rock piles on the smaller streams indicate that placer mining operations have been extensive, and it is reported that some streams have been reworked several times. Many of the steep intermittent tributary streams also are bordered by rock dumps.

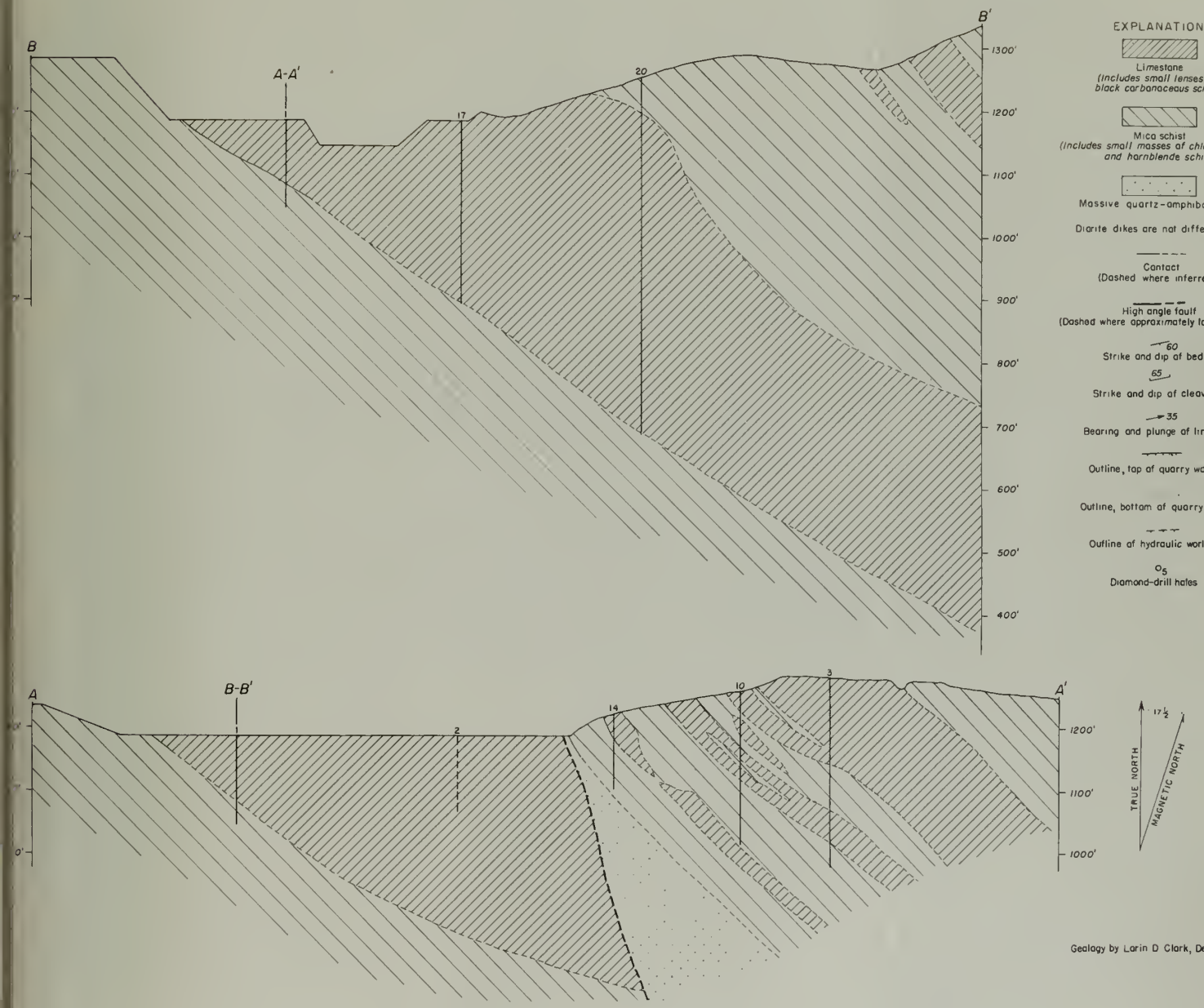
Exploitation of the Tertiary gravels has been extensive, and the amount of gravel remaining in place is probably less than the amount mined. Most mining was by hydraulic methods. Current activity is limited to driving a short drift from the west end of the Rose Hill hydraulic pit.



Base map by Calaveras Cement Company
Quarry outlines revised by Larin D. Clark, December 15, 1950

GEOLOGIC MAP AND CROSS SECTIONS, QUARRY NO. 4

FIGURE 7. Geologic map and cross-sections, Quarry No. 4, Cala



ALAVERAS CEMENT COMPANY, CALAVERAS COUNTY, CALIFORN

100 200 300 400 Feet

Contour interval 20 feet
Datum is approximate mean sea level

ras Cement Co., Calaveras County, California.

Table 4. Gold mines and prospects in Calaveritas quadrangle, California.

Lode

Name of mine, prospect, or shaft	Location Sec.	T. (N)	R. (E)	Bibliography
Alameda and Dalmazia group	25, 26	4	13	XIII, 96; RM; JM 32, 296
Albany	28	4	13	RM
Alpine	20, 21	4	13	XIII, 96; XIV, 68; RM
Bachman	10, 11	3	12	XIV, 69; XXI, 144; B 108, 143; RM; JM 32, 297
Basco	33	4	13	XIV, 70; RM; JM 32, 297
Beatrice (Mayflower)	1	3	13	XII, 90; XIV, 70; RM; JM 32, 397
Belfast	34	5	13	RM
Ben Hur	7	4	13	RM
Bence; Tellurium & Minnie	34	4	13	XIII, 97; XXI, 145; RM; JM 32, 297, 342
	35	6	12	
Big Four	11	3	12	XIV, 70; RM; JM 32, 298
Bigney	21	4	13	RM
Binum	7½ mi. E. of San Andreas			XIII, 98
Blue Ribbon	2, 3	4	13	CCR; JM 32, 299, 249
Bonanza	18	4	13	RM
Bonanza Pocket	2, 11	3	13	JM 32, 299
Bonehard	33, 34	4	13	RM
Bowden	Joins Thorp on N., 6 mi., NW of Eldorado on ridge W. of Salamander Gulch			XIV, 72
Bruce	At Esmeralda			XIV, 72
Bruzza	34	4	13	RM; XIII, 99
Buckhorn Cons. (Red Gold)	1	3	13	XII, 90-91; XIII, 99; XIV, 102; RM; JM 32, 299
California (Hicks)	22	4	13	XIII, 99-100; XIV, 73; JM 32, 300
Cave City	14	4	13	RM
Chapparal & West Ext. of Chapparal	33, 34	4	13	JM 32, 301
Cleveland	8	4	13	RM
Clincher	21	4	13	RM
Columbus	27	4	13	RM
Coralie	27	4	13	RM
Cordova	6	4	13	JM 32, 301
Crown Point & Buckeye	1	3	13	JM 32, 302, 250
Cowbell	20, 21	4	13	Present investigation
Cowbell	22	4	13	RM
Delmazia	25	4	13	RM
Delmetia	7 mi. NW of Murphy on ridge between San Antonio and Indian Creek			XIV, 76
Dragone	1	3	13	JM 32, 303
	36	4	13	
Economic	33	4	13	XIV, 77; JM 32, 303
Eida	4	4	13	XIV, 77; JM 32, 303
Esmeralda	34	4	13	RM
Esmeralda & Sunrise	34	4	13	VIII, 133-135; XIII, 103; XIV, 77, 108; JM 32, 304
Fairplay	1	3	13	JM 32, 304
Falcon (Louisa, Carley)	1	3	13	XII, 94; XIII, 104; JM 32, 304
Fricot group	23, 27	4	13	JM 32, 304, 258; XIV, 80, 87
Claims: Columbus, Rochester, White Pine, New Orleans, Philadelphia, Oswego, Albany, Gov. Davis, Twentieth Century, Horseshoe, Bonanza Placer	28			
Friendship	22	4	13	Present investigation
Gaston Hill	10	4	13	RM
Gertrude	25	4	12	CCR; JM 32, 305
	30	4	13	
Gloy	7	4	13	RM
Golden Star	16	4	13	RM
Grace	34	5	13	RM
Great Divide	1	3	13	XIV, 83; JM 32, 106
Great Western (Right Bower)	4¼ mi. W. of Murphy on ridge between San Antonio and Indian Creek			XIV, 83
Gumboot	26	4	13	JM 32, 262
Hardscrabble (Bull Frog)	6	4	13	JM 32, 307
Harfst	7	4	13	RM
Hercules	19, 24	4	13	XIII, 108; XIV, 86; JM 32, 308
	25, 30			
Hidden Treasure (Manhattan)	1	3	13	JM 32, 308, 312, 264
Highland Mary	2	3	13	RM
Hobart	7	4	13	RM
Homestake & Hostler & Golden Reef	25, 26	4	13	XII, 93; XIII, 108; XIV, 86-87; JM 32, 308
	35			
Hostler	3	4	13	CCR; JM 32, 308
Howard	21	4	13	RM
Idaho Cons.	27	4	13	XIV, 87; RM; JM 32, 308
Claims: Idaho, Grace Darling, Frontenac				
Indian Creek Gold Mng. Co.	34	4	13	XXI, 155; JM 32, 309
Claims: Maria and Fortuna	3	3	13	
Joe Dandy	26, 27	4	13	JM 32, 309
Josephine	½ mi. E. of Esmeralda			XIII, 103
K. & J.	31 (?)	4	13	XIV, 88; RM; JM 32, 310
	34 (?)			
Kelly	3½ mi. W. of Sheep-ranch			XIII, 109
Last Chance	18	4	13	CCR; JM 32, 310, 267
Little Hero	3	4	13	XIV, 90; RM; JM 32, 311
Live Oak, No. 1, No. 2	34	5	13	XIV, 90; RM; JM 32, 311
Live Oak or Halley	2, 3, 10	4	13	RM; JM 32, 311
London	6	4	13	JM 32, 311
	4	4	12	
Lopez	33, 34	4	13	XIV, 92; JM 32, 311, 270
Louisa	3 mi. W. of Murphy			XII, 94
Lucky Jim	18	4	13	JM 32, 311, 270
Main & Fort Ritter	27, 34	5	13	XIV, 92; RM; JM 32, 311
Maria & Fortuna	34	4	13	Calif. Div. Mines, Field Report; JM 32, 312, 271
Markham	22	4	13	RM
Martha	34	5	13	XIV, 92; JM 32, 312
McPherson	30	4	13	JM 32, 314
McQuig (Dodson & McQuig)	2 mi. W. of Murphy			XII, 92; XIII, 112
Max Cons.	25, 26	4	13	JM 32, 312
Meteor	8 mi. E. of San Andreas			XIII, 113
Midwinter & Native Son	10, 11	3	12	CCR; JM 32, 313
Mount Timolus	36	5	12	XIV, 98; JM 32, 314
Murray Creek Cons.	34	5	13	XIII, 114; JM 32, 314
New Discovery	7	4	13	RM
O'Hara	33	5	13	RM
Old McKenney	10, 11	4	13	RM
Old McKinney	10, 11	4	13	XIV, 99; JM 32, 315
Pajaro	21	4	13	RM
Pilot	14	4	13	XIV, 100-101; JM 32, 315
Pioneer	30	4	13	RM
	25	4	12	
Pioneer Lode & Oro Fino P.	30	4	13	JM 32, 316
Pozar	22	4	13	JM 32, 316
Recompense	22, 23	4	13	XIV, 102; JM 32, 317
	26, 27			
Returned & Golden Link	22, 23	4	13	JM 32, 317
Ritter	2½ mi. N. of El Dorado on ridge N. of Murray Creek			XIV, 102
Ritter	34	5	13	RM
Riverside	7	4	12	RM
Rochester	27	4	13	RM
Rose Hill et al. (Rodesina)	5, 8, 25	4	13	XI, 176; XIII, 117; XIV, 102; RM; JM 32, 317
	26			
Searchlight	28	4	12	JM 32, 318
Starlight	17, 16	4	13	XIII, 120; XIV, 107; RM; JM 32, 318
Sunlight	17, 21	4	13	JM 32, 320
Sunrise	34	4	13	XIV, 108; RM; JM 32, 320
Table Mountain	3	4	13	CCR; JM 32, 320
The "400"	5, 6	4	13	XIV, 109; JM 32, 305
Thomas Brothers group	14, 23	4	13	Present investigation
Claims & mines: HO, Yellow Bird, Golden Poppy, Lucky Boy, Rose Marie, Tip Top, Coarse Gold, Mt. Bullion, Cave City, A1, Wheelock				
Thorpe	11	3	12	X, 63; XIII, 121; XIV, 109; B 108, 143; RM; JM 32, 320
Venus	7	4	13	RM
Washington	19	4	13	RM
Wheelock	23	4	13	XIII, 123; XIV, 112; JM 32, 323
Wilferd Due & Co's.	7	4	13	RM
Winchester	21	4	13	RM
Wonder	18	4	13	RM

Table 4. Gold mines and prospects in Calaveritas quadrangle, California—Continued.

Placer

Name of mine, prospect, or shaft	Location Sec.	T. (N)	R. (E)	Bibliography
nalia	27	4	13	RM; CCR; JM 32, 356
ıstrian Hill	11	4	13	JM 32, 356
rnhardt	25	4	12	CCR; JM 32, 356
g Nugget	15	4	13	JM 32, 357
ue Wing	29	4	13	CCR
adford	8	4	13	CCR
andy Flat (Bradley Flat)	26	4	12	CCR; JM 32, 357
laveritas Hill Cons.	35	4	12	XIV, 115; B 413, 93; JM 32, 357, 332
ain Hill & Swiss	19, 30	4	13	JM 37, 357
eveland (Foley)	32	5	13	RM
lumbo & John McLaughlin P. Mine Tailing	25	4	12	CCR; JM 32, 358
llar et al.	1; 11 30, 36	4	13	JM 32, 358
nery group	8, 9	4	13	XIV, 117; 118; B 18, 124-125
Claims: Humboldt, Rose Hill, Perano, Valley Land, Bradford, Pasche Bush	10, 11	4	13	JM 32, 358
eccero	19, 20	4	13	CCR; JM 32, 359
ston Hill	9, 10 32	4 5	13 13	XIV, 118; JM 32, 359
enn	31	5	13	XIX, 18; PR 8, 29; JM 32, 359
ose Neck	8	4	13	CCR
andy Flat	26	4	12	JM 32, 359
ub Hill	25	4	12	RM
erin	35	4	13	CCR; JM 32, 359
nter & Martlief	19, 20	4	13	CCR
Hidden Cave	10, 11	4	13	CCR; JM 32, 359
Junction	31	4	13	CCR
La Capelle Flat	8	4	13	JM 32, 360
Last Chance	18	4	13	CCR
Leap Year	27	4	13	RM
Line Stone & Mohawk	1, 11, 12	4	13	JM 32, 360
Long Tunnel	26	4	12	CCR
Matthavale	34	5	13	JM 32, 361
Mountain Ranch	5	4	13	CCR; B 413, 90; JM 32, 361
Mountain Ranch	29, 32	5	13	JM 32, 361
Old McGregor & Old McGregor No. 2	13	4	12	JM 32, 361
Ore Finea Diggings	28, 29	4	13	JM 32, 361
Oro Fino	30	4	13	CCR
Railroad	35	4	12	JM 32, 362
Railroad Hill	2	3	12	CCR; JM 32, 362
Richie Hill	26	4	12	CCR; JM 32, 362
Riley Boys	10	4	13	CCR; JM 32, 362
Rose Hill	8	4	13	RM
Table Mountain Gravel et al.	5	2	14	JM 32, 363
	1	4	13	
	11, 12	4	13	
	6, 7	4	13	
Tisher	32	5	13	RM
Valle	19	4	13	CCR
Watson	25	5	12	JM 32, 364
	31	5	13	
Willow Creek	28	4	12	JM 32, 364

M: Register of Mines and Minerals 1899, California State Mining Bureau.
IV, 117: Fourteenth report of the State Mineralogist, California State Mining Bureau, 1915, p. 117.
CR: Calaveras County records.
M 32, 356: California Journal of Mines and Geology, vol. 32, 1936, p. 356.
413, 90: Bulletin 413, U. S. Bureau of Mines, p. 90.
R 829: Preliminary report, California State Division of Mines.

The quadrangle lies in the East Belt of the Mother ode region, and as elsewhere in this belt the bed rock ines are small and the gold-bearing veins are short and scontinuous. Records indicate that few if any of the ines include a total of more than 1,000 feet of workgs. Many of the workings are still accessible. Although uch of the vein material is barren or of moderate ade, pockets of exceedingly rich ore are reported to ve been found in several mines, leading to the popular signation "pocket mine" belt for this gold-bearing ne that lies east of the Mother Lode.

Gold mines in the quadrangle have been listed in ble 4.

Chromium

A small tonnage of chromite is reported to have been oduced from a mine on the northeast side of Ponrosa Way in the SW¼NE¼ sec. 2, T. 3 N., R. 13 E., ring World War I; about 100 tons of chromite from stockpile at the mine is reported to have been shipped ring World War II. The dump of a caved adit or ench 400 feet southwest of the mine contains chromite, d disseminated chromite is present in the antigorite ck in the intervening area. Chromite is also present the dump of a shallow prospect shaft in the small ns of antigorite rock in the NW¼NE¼ sec. 2, T. 3 N., . 13 E. The chromite masses are apparently small.

Copper

Copper is reported by local residents to have been oduced, probably before 1908, from a mine north of an Domingo Creek in the NW¼ sec. 2, T. 3 N., R. 13 E., but no published records are available, and the shaft is caved. The Bund mine is a copper prospect in sec. 12, T. 3 N., R. 12 E., with no published record of production. The shaft is not accessible, and the amount of workings is not known. Bornite and azurite are present in the walls and dump of a shallow caved prospect pit in the SW¼NE¼ sec. 2, T. 3 N., R. 13 E.

Iron

Shallow cuts in several of the masses of ferruginous chert replacing limestone attest to some interest in these deposits as sources of iron ore or possibly of paint pigment. This material consists of red and brown iron oxides intimately mixed with chert in various proportions. The best material appears to be massive iron oxide with very little chert, and some samples might show a high iron content. However, the highest-grade material forms a very small proportion of all deposits observed, and it is unlikely that any of the deposits in this quadrangle could yield more than a few hundred tons of ore.

Massive magnetite interlayered with antigorite is present on the dump of a shallow caved prospect pit in the SE¼NE¼ sec. 2, T. 3 N., R. 13 E. The magnetite layers are as much as half an inch thick. Most of the rock shows less than 50 percent magnetite.

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